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BIPOLAR PLATE FOR FUEL CELL AND USE THEREOF

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(71) Applicant *(for all designated States except US)*: CELLKRAFT AB [SE/SE]; Björnnäsvägen 21, S-113 47 Stockholm (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: OCKLIND, Anders [SE/SE]; Sedelvägen 46 B, S-129 32 Hägersten (SE). NORDLUND, Joakim [SE/SE]; Göran Persons v 33, S-171 55 Solna (SE).

(74) Agents: STOCKHOLMS PATENTBYRÅ ZACCO AB et al.; P.O. Box 23101, Sveavägen 170, S-104 35 Stockholm (SE).

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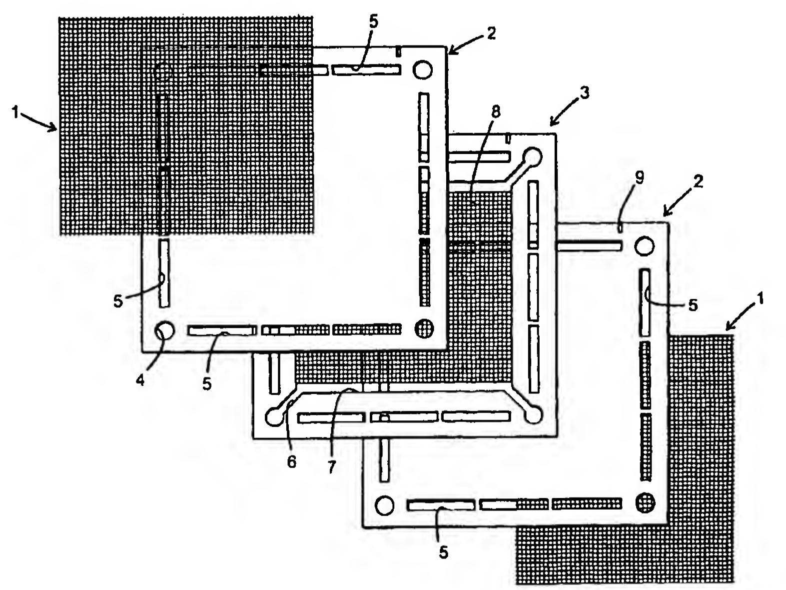

(57) **Abstract:** A bipolar plate (10) for a fuel cell or chemical reactor is described comprising one distribution component (1) on each side of ametal layer for distribution of a gas across the surface of a cathode and the surface on an anode. The distribution components are constituted by rectangular gas distribution layers (1), which are fixed soldered centred onto the metal layer. Gas flow channels (5) are arranged for transverse flow along opposite edges of the gas distribution layer. A compact design with a particularly low through-flow resistance is in this way achieved.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Bipolar Plate for Fuel Cell and Use Thereof

Area of Application for the Invention

The present invention concerns a bipolar plate for fuel cells and the use of the bipolar plate in the construction of a fuel cell or stack of fuel cells, and its use in electrochemical reactors.

Background to the Invention

Bipolar plates constitute an important component in fuel cells, whose function has been known for over 100 years. The fuel cell converts the chemical energy present in a fuel, normally hydrogen gas or methanol, directly to electricity by electrochemical oxidation. Fuel cells are characterised by high conversion efficiency and the absence of any exhaust fumes dangerous to the environment or to health. The development of solid polymer electrolytes has made it possible to construct fuel cells that are robust, simple and more compact than previously. The functionality that was previously achieved using electrolytes in the form of a fluid can be achieved with a solid polymer electrolyte, which is constituted by a thin polymer membrane. The characteristic properties of the membrane include low permeability for gases, low electrical conductivity and high proton conductivity. The last-mentioned property is what has given this type of fuel cell the name (in English) "Proton Exchange Membrane Fuel Cell", abbreviated as "PEMFC". Major research resources have been focussed onto PEMFC during recent years in industry and in the academic world. The possibility of using fuel cells as a clean and efficient replacement for combustion engines is the application that has driven development forward. The most offensive industrial initiative has been taken by DaimlerChrysler, Toyota and GM. DaimlerChrysler will commence the sale of fuel cell-powered buses on a small scale during 2002-2003.

Research and development in fuel cells are principally directed towards reducing costs, improving performance and extending the lifetime. The most expensive components in a fuel cell stack are constituted by the membrane, the catalyst and the bipolar plate. The membrane is manufactured in a complex process involving several stages. The catalyst is constituted by expensive inert metals such as platinum and ruthenium. The bipolar plate is normally constituted by graphite or stainless steel into which tracks have been fixed in

order to function as flow channels for the fuel gas and for air.

The function of the bipolar plate with respect to the above-mention fuel cells is to lead gases to both sides of the membrane with its attached electrodes. This is known as the "membrane-electrode assembly" (MEA) and constitutes the active part of the fuel cell stack. Furthermore, the plates are to lead current from one cell to the next and in this way connect the individual cells in series. Finally, the plates are to cool the cells of the stack by distributing cooling water. The properties that are desired for a bipolar plate are thinness, low cost, high conductivity and heat conductivity, resistance to corrosion, and mechanical stability. It is also important that the distribution of flow within each cell and between cells in the stack is even, and it is important that the bipolar plate has a relatively large active area where the gases are distributed, with a relatively small passive part around this in order to give the stack a high density of efficiency.

The above-mentioned bipolar plates find their use in fuel cells, but they can also be generally used in electrochemical reactors for electrolysis, etc.
The most commonly used material for bipolar plates is graphite, which has a high electrical conductivity and good resistance to corrosion, although it is expensive and fragile. Other materials that have been tested are titanium, polymers with a graphite mixture (Grafoil, registered trade mark), and aluminium.

Machine-milled channels have been suggested, for example in USP 5981098, for the distribution of gases, while the use of porous layers is revealed by 5482792.

USP 6037072 reveals the use of a metal mesh as the gas-distributing component in fuel cells. The metal mesh thus performs the function or spreading the gases across the surfaces of the electrodes - the cathode of one neighbouring cell and the anode of one cell on the opposite side. A thin foil between the meshes has the function of separating the gases - air or oxygen gas for the cathode, and hydrogen gas or a hydrogen gas mixture, or alternatively methanol/water mixture, for the anode. The design is based, however, on diagonal gas flows across the mesh, which in turn involves a considerable resistance to current, due to high flow rates, at the narrow entrance opening at the corner of the flow region.

Detailed Description of the Invention

The invention concerns a bipolar plate with two gas-distribution patterns and one intermediate metal layer, which have been joined together by means of soldering/welding to a compact unit that distributes gas to the anode of a cell on one side and to the cathode of another cell on its other side.

The bipolar plate can be produced in two embodiments as follows.
The first embodiment has in the present case the description "bipolar plate without internal cooling", and comprises only the three components that have been described above, which are constituted by two external gas-distribution layers for the distribution of gas and an intermediate separation layer.

The second embodiment is described in the present case as "bipolar cooling plate", in which cooling agent circulates within the bipolar plate. One component of the bipolar cooling plate consists of a mesh with a framework of metal that lies in the same plane and has the same thickness. The cooling agent flows through the mesh. A separation layer lies on both sides of the mesh with an external gas-distribution layer for the distribution of gas. The present bipolar cooling plate thus consists of five components.

The gas-distribution layer can, for example, be a mesh built up from metal wire or it can be constituted by other layers permeable to gas that have a porous structure and a high electrical conductivity/heat conductivity, such as meshes of straight or loop-formed metal wire, expanded/stretched sheet metal with a porous mesh structure, sintered metal material or another porous structure with a low resistance to flow in the x, y and/or z-directions, for example, based on metallised cellular plastic with open pores. The metal meshes can be mass-produced and can be cut to size using simple and well-established processes. Thus, metal sheets for the separation layers can in the same way be processed at a large scale, for example, by punching or laser-cutting to the final shape for the pre-determined design.

The meshes, which can additionally function as supporting elements in the two designs, are constituted by one mesh for the distribution of gas to the anode and one mesh for the distribution of gas to the cathode, together with a cooling mesh for distribution of the

cooling agent. The requirements for even distribution are not as severe for the cooling circuit as they are for the gas circuits. The principal function of the cooling mesh is, instead, to make possible high electrical conductance in that it connects directly the two separation layers with each other. By filling up the equivalent space within the cooling frame, it further constitutes a mechanical support such that the plate does not acquire a concave geometry when the stack is placed under pressure, something that would lead to an uneven pressure and a high contact resistance at the transitions between plate and electrode. The mesh structures of the meshes can be designed differently with respect to, for example, wire thickness and mesh aperture, and they may be specially designed for the fluid and for the pre-determined flow conditions.

The separation layer is the same for the bipolar plate without cooling, where it exists in the form of one component, as it is in the bipolar cooled plate, where it exists in the form of two components.

The various components are joined together preferably by soldering to the relevant type of bipolar plate, and in this way a compact and easily assembled flat element is achieved for the construction of fuel cell stacks and cell stacks of chemical reactors. The unit demonstrates excellent electrical conductivity, heat conductivity, mechanical stability and resistance to leaks.
When assembling the separate flat units with the relevant cell stacks, intermediate gaskets, the geometry of which will be revealed by the following description, are inserted in order to prevent leaks. The gaskets are made from an elastic material with a high resistance to acid, alkali and heat, such as, for example, silicone rubber or an equivalent polymer material.

In the attached drawings, preferred examples of the two embodiments of the invention are reproduced as a frontal view in:

Fig. 1 the components of the bipolar plate,
Fig. 2 the components of the bipolar plate without internal cooling,
Fig. 3 the cooling layer in the bipolar cooling plate, and in
Fig. 4 the gas meshes on the separation layer.

To start with, we turn to **Fig. 1,** in which the five layers of the bipolar cooling plate are reproduced. The gas mesh (1) is located uppermost, in contact with the MEA. The mesh is fixed soldered to the underlying separation layer (2), that is, to a plate whose function is to limit the gas flow. The layer can be as thin as the soldering process allows, whereby the thickness of the sheet preferably lies within the interval 0.1 - 0.5 mm. Openings for the gas flows (5) and for cooling water (4) are located around the perimeter of the separation layer. The gas mesh is designed in a rectangular form such that it passes out between the gas channels (5) on opposite sides and in this way makes flow between these possible. The gas passage along one side is preferably divided into a small number of channels, in this case three in number, via equivalent openings in the separation layer. The layer obtains a firm support through the metal surfaces that separate the openings, and handling during manufacture is simplified.

According to one important aspect of the invention, the gas mesh lies only next to the gas channels (5) at two opposite edges of the separation layer (2), and mesh flow is only possible between these two opposite edges once the free metal surfaces of the flat element that has been soldered together have been provided with a superficial gasket around the gas mesh. The gasket prevents mesh flow between the two remaining edges of the separation layer.

The indentations (9) that have been arranged above the two separation layers and the intermediate layer are intended to function as connection points for measurement of the potential of the bipolar plate though contact pins, and in this way make individual voltage monitoring of the different cells possible. The voltage at each of the cells in the stack is to lie at the same level varying between 0.5 and 1 Volt. A cell voltage that deviates by being low constitutes a fault indication. It may, for example, be a matter of a membrane having a moisture level that is too low, or it may be that air or hydrogen gas has not been supplied at the rate at which it is consumed, whereby the cell becomes quenched and can be damaged.

The intermediate layer (3), which is located under the upper mesh (1) and the inferior separation layer (2) in **Fig. 1,** is the cooling layer (3), and it is constituted by a metal frame-cooling frame in which a cooling mesh (8) with cooling function has been placed.

The cooling frame encloses completely the gas channels but it contains slots (6) from the four cooling channels (4) at the corners. The cooling agent, for example water, will be forced in via the two slots at the bottom, and the cooling agent will flow out through the two slots at the top. The width of the slots lies, depending on the dimensions of the plate, preferably within the interval 0.2 - 0.7 mm. One slot (7) between the cooling mesh and the cooling frame at the inlet and at the outlet improves, furthermore, the distribution of the cooling water from the slots in the corners across the complete area of the mesh. The cooling mesh is completely enclosed within the cavity that is formed by the cooling frame and the separation layers that have been soldered together. The thickness of the cooling frame and that of the cooling mesh must agree in order to give a flat design. When soldering/welding together the cooling mesh and the cooling frame with the superior and inferior surfaces, it is attempted to obtain good electrical conductivity between the layers and prevention of leakage from the gas and water channels.

The fourth layer according to **Fig. 1** is constituted by the second separation layer (2). A gas mesh has been soldered onto the reverse side of this with the purpose of leading a second gas flow, for example air, via the mesh (1) across the neighbouring MEA. This gas mesh has been rotated by 90° relative to the previously mentioned upper gas mesh for, for example, a hydrogen gas flow. In this way, the channels (5) at the top and the bottom are connected via the mesh for gas supply and for gas exhaust. The principle of gas flows via the gas meshes with a 90° rotation is made most clear by **Fig. 4**, which concerns a frontal view from the front and rear surfaces of the bipolar plate.

An example is reproduced in **Fig. 2** of an embodiment of the bipolar plate according to the invention without inner cooling. The design is similar to that of the bipolar cooling plate, with the difference that the cooling layer and one separation layer have been omitted. This means that the gas meshes (1) are fixed soldered at the front and rear surfaces of the same separation layer (2). Note that the rotation of the gas meshes agrees with what has been described with respect to the bipolar cooling plate.

Through the present solution, it has been possible relative to previous technology to, among other improvements, eliminate the pressure losses in the gas flow that, for example, in USP 6037072 includes diagonal flow pathways across the electrode surfaces. The

transverse gas flow that according to the present invention is thus achieved across the relevant plate surfaces results in low flow resistance through the significantly larger inlet and outlet areas.

The cooling layer, which has been described in the earlier description as an integral part of the bipolar cooling plate, is made more clear in **Fig. 3.** The cooling mesh is centred in the framework such that in this way a slot (7) is obtained between the lower frame edge and the mesh, and a slot (7) is obtained at the top between the frame edge and the mesh. This gives rise to a channel for distribution of the incoming flows at the bottom and the outgoing flows at the top. In the same way, the cooling flow will be distributed evenly across the complete area, while at the same time the loss of pressure is minimised.

Fig. 4 reveals more clearly the orientation of the gas meshes on the separation layers. The gas meshes (1) are placed centered onto the separation layers (2). In the case of the bipolar cooling plate, the gas mesh is placed on one of the separation layers such that the mesh structure joins the inlet flow channels (5) along the sides. The gas mesh is placed on the opposite side of a second separation layer such that the mesh structure joins the inlet flow channels at the top and bottom. The cooling frame (3) and mesh are placed between the two separation layers. In the case of the bipolar plate without internal cooling, finally, the gas meshes are placed according to what has been described previously, although in this case they are located on one and the same separation layer.

The present bipolar plates offer several advantages: the soldering gives a very high electrical conductivity, something that minimises electrical losses. In the same way, high heat conductivity is a consequence of the soldering and of the choice of material, and this facilitates cooling. Due to the transverse flows, which emerge from openings, and which are distributed along the complete length of the edge, the gas distribution will be extremely homogenous across each cell surface, something that is a condition required for efficient use of added reactants. The broad supply minimises the fall in pressure, which limits the work of the compressor required to force air through the stack. The use of well-defined metal meshes also makes a very small spread of the fall in pressure through different cells possible, which means that the distribution of flow between the cells in the stack will be very even. Furthermore, a robust and compact construction of the bipolar plate is made

possible by the simple design of the individual components.

Claims

1. A bipolar plate for a fuel cell or electrochemical reactor, comprising a distribution component (1) on each outer surface of a metal layer (2) for the distribution of gas across a cathode surface and across an anode surface, **characterised** in that the plate is constituted by a unit (10) of metal, soldered or welded together, with passages for the flow of gas (5) and cooling agent (4), whereby:

a) one distribution component in the form of a gas distribution layer (1) is centrally fixed, preferably by soldering, on each side of the metal layer for distribution of gas to the surface of the cathode and the surface of the anode;
b) openings (5) are located in the metal layer towards the electrode surfaces in the lower and upper edges of the metal layer and each of the edges placed at the sides, with a longitudinal location outside of the gas distribution layer (1) and with an extension along the complete length of the edge for flow of gas via the gas distribution layer (1) across each electrode surface;
c) the gas distribution layer (1) against each electrode surface is in contact with openings (5) at two opposite edges, whereby the flow pathway of the gas across the cathode surface is oriented perpendicularly to the equivalent flow pathway across the anode surface;
d) passages (4) are located at each corner of the metal layer for the flow of cooling agent, whereby a separate cooling circuit may be integrated into the metal layer (2, 3, 2).

2. The bipolar plate for a fuel cell according to claim 1, **characterised** in that one cooling circuit (3) has been integrated with the metal layer, whereby the metal layer is constructed from three layer elements (2, 3, 2) comprising two outer separation layers (2) with an intermediate layer element (3) in the form of a cooling frame soldered together, together with a fixed soldered cooling mesh (8) for distribution of the cooling agent, which mesh is in this way enclosed, whereby the flow pathways for gas (5) and for cooling agent (4) coincide with equivalent passages located in the framework, and that slots (6) emerge from each passage for cooling agent in the intermediate layer element to a neighbouring corner of the cooling mesh (8) for distribution of the cooling agent.

3. The bipolar plate for a fuel cell according to claim 2, **characterised** in that the cooling

mesh (8) is centred in the intermediate layer element (3) for distribution of the cooling agent and that it makes contact with two opposite edges of the cooling frame (3) and that slots (7) emerge along the two remaining edges in association with the slots (6) that emerge from each passage for cooling agent between the edges and the cooling mesh (8) for flow through the slots (7) and distribution of the cooling agent via the cooling mesh (8).

4 The bipolar plate for a fuel cell according to claims 1 to 3, **characterised** in that the gas distribution layer (1) and the cooling mesh (8) are constituted by meshes built up from straight metal wire, or metal wire in the form of a loop.

5. The bipolar plate for a fuel cell according to claims 1 to 3, **characterised** in that the gas distribution layer (1) is constituted by porous material with a low flow resistance and high conductivity, preferably stretched/expanded sheet metal with a mesh structure, sintered metal material or metallised cellular plastic.

6. The bipolar plate for a fuel cell according to any one of the preceding claims, **characterised** in that the separation layers (2) and the cooling frame (3) have been cut by laser cutting.

7. The bipolar plate for a fuel cell according to claims 1 to 3, **characterised** in that the openings (4, 5, 6) in the intermediate metal layer and in the separation layers (2) and the cooling frame (3) have been obtained by punching.

8. The bipolar plate for a fuel cell according to any one of the preceding claims, **characterised** in that indentations (9) have been arranged in the edge area of the separation layer (2) and/or the cooling frame (3) intended to function as connecting points for potential measurement of individual cells via contact pins.

9. The bipolar plate for a fuel cell according to any one of the preceding claims, **characterised** furthermore in that gaskets have been arranged that surround the gas distribution layers (2) on each side of the plate and make contact with the free plate surfaces and that these gaskets are equipped with openings that coincide with all passages.

10. The use of a bipolar plate according to claims 1-9, for the construction of a fuel cell stack or an electrochemical reactor.

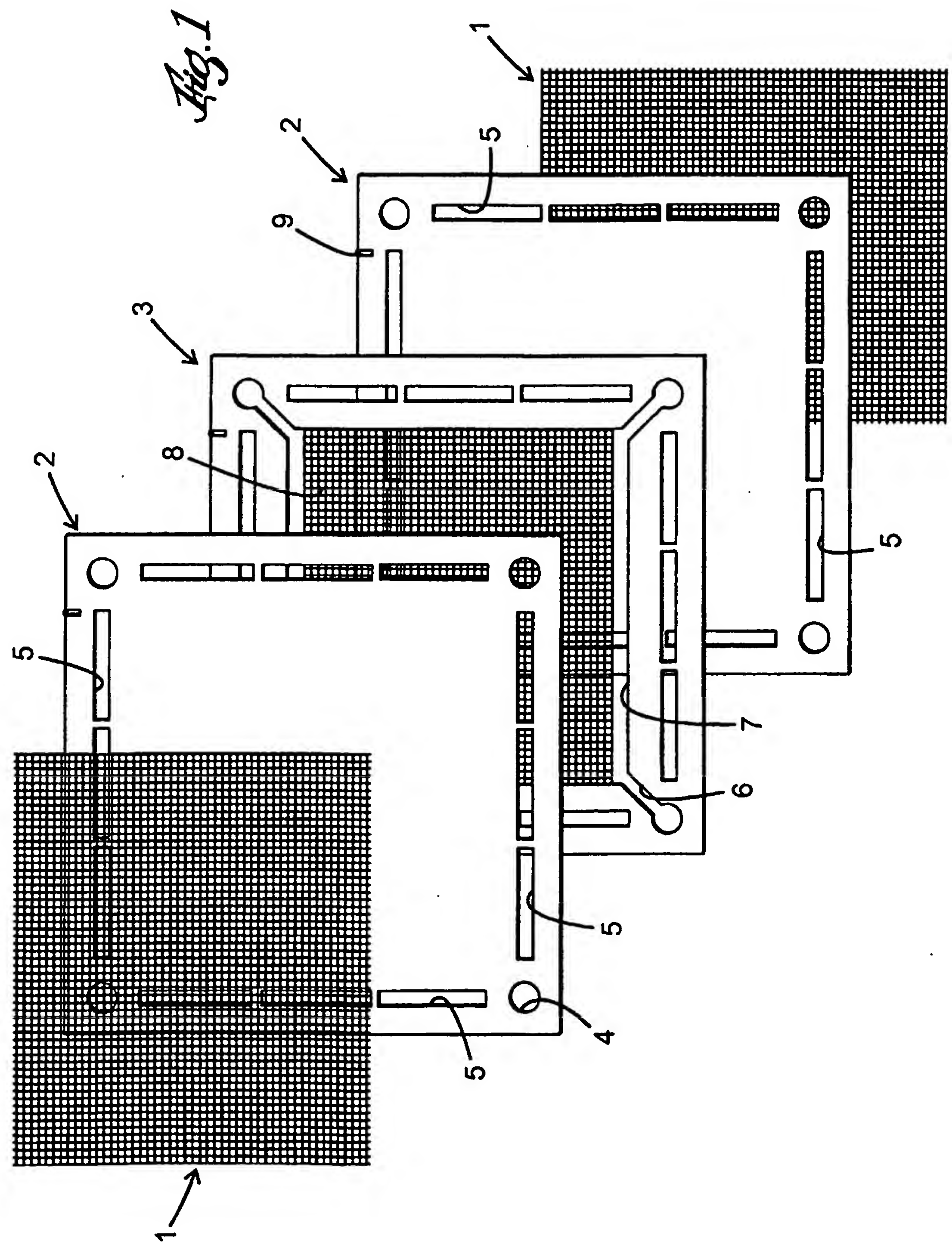


Fig.1

Fig.2

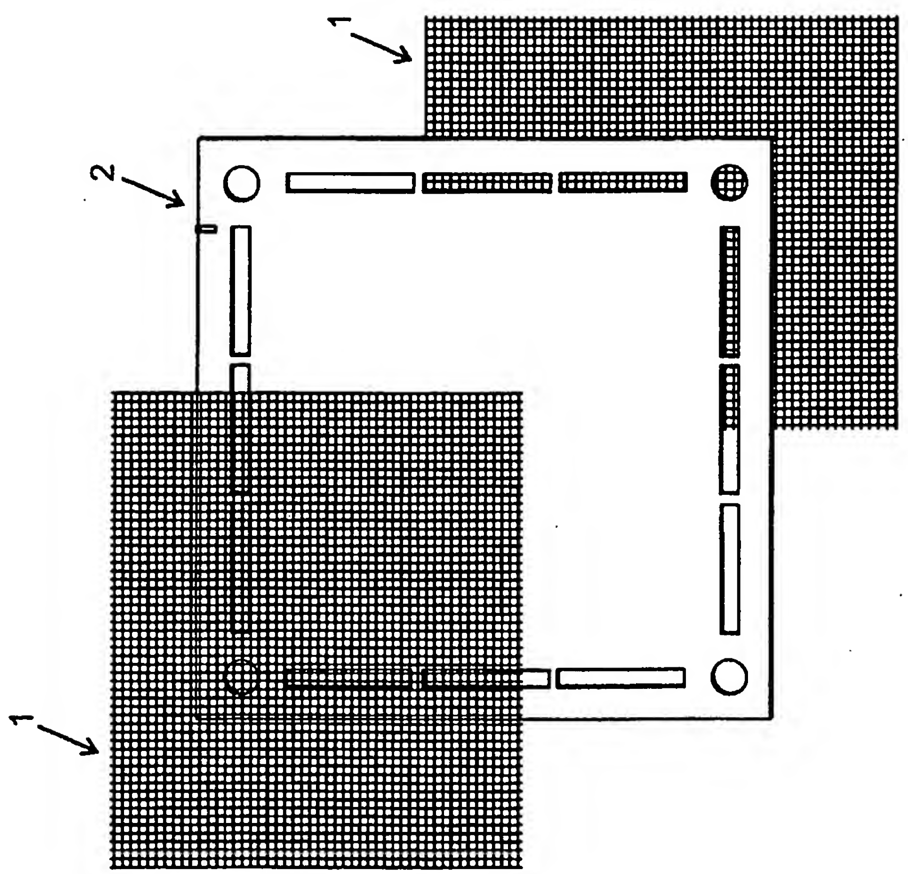
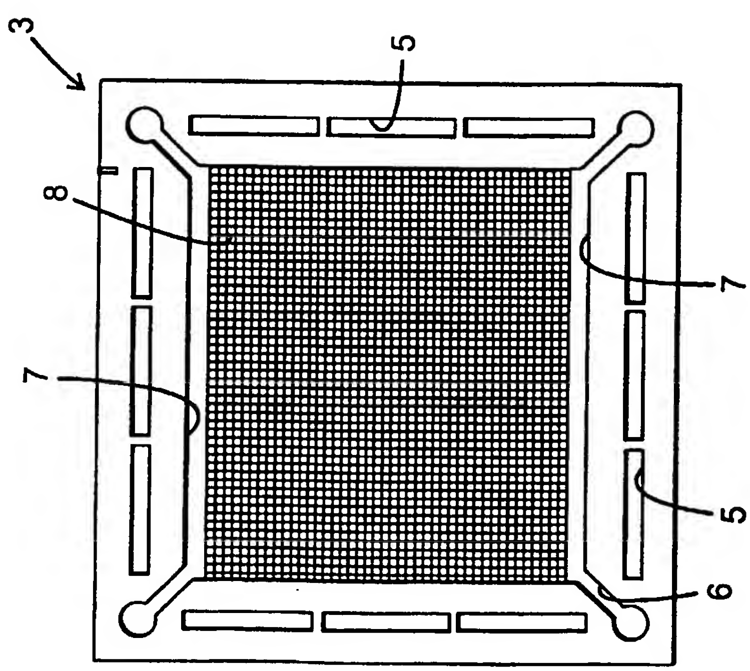


Fig. 3



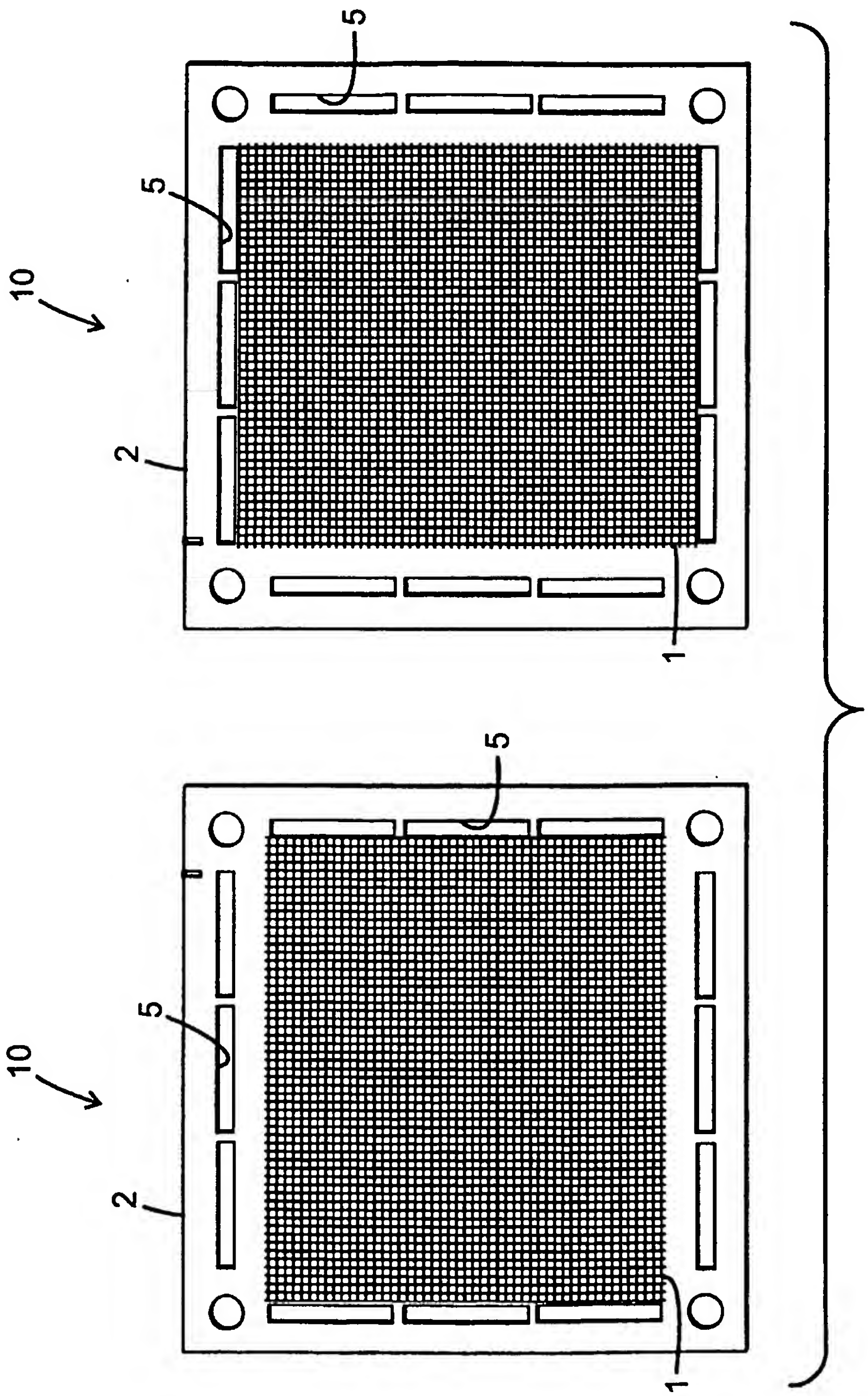


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/00201

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H01M 8/02, H01M 8/24, C25B 9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6037072 A (MAHLON S. WILSON ET AL), 14 March 2000 (14.03.00), column 4, line 25 - column 5, line 4; column 8, line 65 - column 9, line 15 --	1-10
A	WO 0069003 A2 (LYNNTECH, INC.), 16 November 2000 (16.11.00), page 7, line 1 - line 17 --	1-10
P,A	WO 0147049 A1 (PROTON ENERGY SYSTEMS, INC.), 28 June 2001 (28.06.01), page 6, line 18 - page 7, line 2 -- --------	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

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Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Ulla Granlund/MP Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/01/02

International application No.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6037072 A	14/03/00	US 6207310 B	27/03/01
		AU 4502397 A	17/04/98
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WO 0069003 A2	16/11/00	AU 4816500 A	21/11/00
		US 6232010 B	15/05/01
WO 0147049 A1	28/06/01	AU 2291201 A	03/07/01
		US 2001049044 A	06/12/01